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An automated system for assessing the seismic resistance of buildings and structures using regulatory documents

D.A. Bekmirzaev[1], I. Mirzaev[2,3], R.R. Yuldoshev[2]

[1]Institute of Mechanics and Seismic Stability of Structures named after M.T. Urazbaev, Tashkent, Uzbekistan

[2]National Research Institute for Seismic Safety and Resilient Construction under Tashkent Institute of Architecture and Civil Engineering, Tashkent, Uzbekistan

[3]Tashkent State Transport University, Tashkent, Uzbekistan

Abstract: This paper proposes an automated system that compares building information with applicable construction requirements. The aim is to make preliminary seismic assessment easier to understand, repeat and review. The method combines a digital building record, an approved list of regulatory rules, engineering calculations and a report that identifies the source of each result. Every applicable check has one of three outcomes: pass, fail or not checked because evidence is insufficient. Four equations describe the demand-to-capacity ratio, storey drift, assessment coverage and the pass rate of completed checks. A synthetic example contains five checks: two pass, one fails and two remain unresolved. Coverage is therefore 60%, while the pass rate is 66.7%. These percentages describe the checklist, not the probability of surviving an earthquake. The main contribution is a transparent decision process that keeps confirmed deficiencies separate from missing evidence. The example demonstrates the method; field validation and a qualified engineer's final assessment are still required.

Keywords: seismic resistance, existing buildings, regulatory requirements, automated checking, building passport, structural assessment

1. Introduction

Seismic resistance is the ability of a structure to meet a specified performance requirement under earthquake loading. It cannot be determined from the construction year or the number of storeys alone. Engineers need information about the site, structural system, materials, connections, foundations and existing damage. ISO 13822 provides a general basis for assessing existing structures [5]. ASCE/SEI 41-23 provides a performance-based framework for seismic evaluation [6]. Rapid visual screening serves a more limited purpose: it helps identify buildings that need further investigation [7].

In many building inventories, information is stored in a building passport: a digital record containing the building's identity, location, dimensions, structural characteristics and inspection documents.
A passport is useful, but it is not a complete structural model. The supplied manuscript describes a system for searching regulatory documents using such records [11]. The present study develops that idea into a clearly defined checking procedure.

The research question is how to turn building data and regulatory text into a result that another engineer can verify. Earlier studies show the importance of translating requirements into explicit computer rules [8, 9]. Here, the proposed system links every result to its input evidence and regulatory source. Document search helps find the requirement; an approved calculation or comparison determines the result.

2. Research methodology

Documents used in the proposed system

A regulatory document is an official standard or rule that defines an applicable technical requirement. For Uzbekistan, the proposed rule database starts with the documents in Table 1. QMQ 2.01.03-19 is identified in the reference list of ShNQ 1.04.01-23 [1, 2]. The latter also addresses technical investigation and monitoring of existing buildings. Material-specific requirements are obtained from the relevant concrete or masonry standard [3, 4].

Table 1

Main documents and the information they support

Document	Subject	Use in the system
QMQ 2.01.03-19 [1]	Construction in seismic regions	Seismic requirements and analysis basis
ShNQ 1.04.01-23 [2]	Technical investigation and monitoring	Inspection evidence and condition assessment
ShNQ 2.03.01-24 [3]	Concrete and reinforced-concrete structures	Applicable material and member checks
ShNQ 2.03.07-21 [4]	Masonry and reinforced masonry	Applicable masonry checks

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Source: official records and cross-references [1–4]. English document titles are translations.

Table 1 is a starting point, not a complete assessment checklist. A real project may also require standards for loads, soils, foundations and nonstructural elements. Each document must be checked for its scope, effective edition and amendments. A recent publication date alone does not prove that a document applies to a particular building. International references [5–7] provide methodological guidance; their numerical limits must not be mixed with national rules without an approved assessment basis.

Building information and rule preparation

The minimum input includes building identification, location, use, storey count, dimensions, structural system, material test results and inspection findings. Where a calculation is needed, the system also requires a suitable structural model and the relevant loading and foundation information. Each value is stored together with its unit, source document, observation date and verification status. An unverified statement is not treated as a measured property.

Before a requirement is automated, an engineer prepares a rule record. This record states the document and clause, the buildings to which it applies, the required inputs, the comparison to perform and the explanation to show. For example, a member-strength rule compares the calculated force with the corresponding design resistance. The program must use compatible units and the same assessment basis for both values.

The supplied material does not provide an independently verified set of building calculations and expert decisions. This paper therefore presents a proposed method and a synthetic example, not a measured accuracy study. Exact clause-specific limits must be taken from the approved full text before the system is used on real buildings.

Assessment method and equations

For each requirement, the system first checks applicability and evidence. It then returns pass if the requirement is satisfied, fail if reliable evidence shows a violation, or not checked if the evidence is insufficient. Requirements outside the building's scope are excluded only after the reason is recorded. A missing test result must never be counted as a pass.

Demand-to-capacity ratio

For a force-controlled strength check, the calculated demand is divided by the corresponding design resistance:

$$\rho_j = \frac{E_{d,j}}{R_{d,j}}, \qquad R_{d,j} > 0 \tag{1}$$

Here, ρ_j is the demand-to-capacity ratio for check j; $E_{d,j}$ is the calculated force or moment; and $R_{d,j}$ is the corresponding design resistance. Use a nonnegative demand magnitude, a positive resistance and matching units. A value of $\rho_j \leq 1$ satisfies this strength check; $\rho_j > 1$ indicates that demand exceeds resistance. For example, 180 kN divided by 200 kN gives 0.90. The result applies only to that check, not to the whole building.

Demand and resistance must come from suitable engineering calculations, with the load combinations, material properties and factors required by the selected assessment method. Equation (1) does not replace deformation, detailing, foundation or stability checks.

Storey drift ratio

Storey drift describes the relative horizontal movement between two adjacent floors:

$$\theta_i = \frac{|\Delta_i|}{h_i} \tag{2}$$

Here, θ_i is the drift ratio of storey i; Δ_i is its relative horizontal displacement from the structural analysis; and h_i is the storey height. Displacement and height must have the same units. The result is compared with the applicable limit, θ_{lim}. For example, 9 mm divided by 3,000 mm equals 0.003, or 0.3%. The allowable limit depends on the selected code and performance requirement [1, 6].

What the two summary percentages mean

Assessment coverage shows how many applicable checks have enough reliable evidence to be completed:

$$C = \frac{N_e}{N_a} \times 100\% \tag{3}$$

N_a is the number of applicable checks in the approved checklist, and N_e is the number completed. Both passed and failed checks are completed checks. The pass rate considers only the completed checks:

$$P = \frac{N_p}{N_e} \times 100\% \tag{4}$$

N_p is the number of passed checks. Coverage C is undefined when $N_a = 0$; pass rate P is undefined when $N_e = 0$. These are unweighted reporting indicators, not a safety class or an earthquake-survival probability. Every failed check remains visible even if P is high. Unknown applicability must be resolved before the summary is used.

Proposed system operation

The system has four main tasks: collect the building evidence, find the applicable requirement, carry out the check and explain the result. The supplied manuscript describes the document-search component [11]. The checking procedure below is the proposed extension; the screenshot alone does not demonstrate that this procedure has been implemented or validated.

Data collection. The operator selects a building record and attaches drawings, inspection reports and test results. The system checks units and flags empty or contradictory fields. An engineer confirms whether the information is suitable for the intended assessment.

Rule selection. Document search retrieves relevant clauses. Retrieval-augmented generation means finding supporting text before drafting an answer [10]. In this system, it helps explain the source; it does not create an engineering requirement or decide that a building is safe.

Checking and reporting. Approved rules compare verified values or engineering calculation results. The report lists the evidence, document and clause, calculation, outcome and required follow-up. If evidence is missing, it names the missing information. A qualified engineer reviews the report and determines any further investigation.

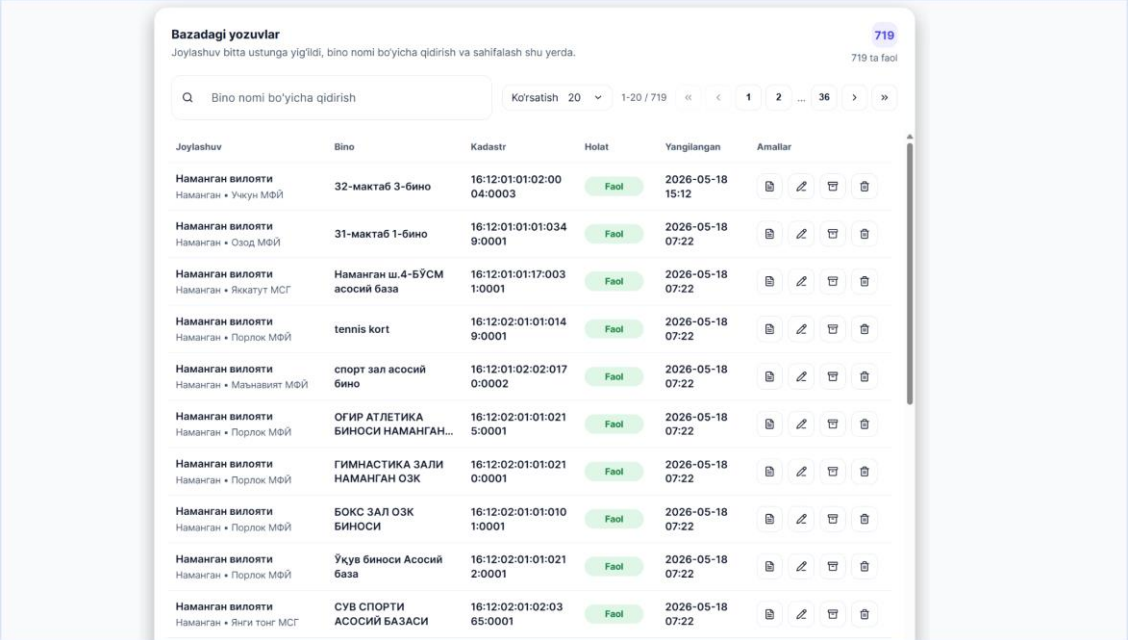


Fig. 1. Supplied building-inventory interface. The displayed 719 active records describe the inventory, not validated seismic-assessment results

In Figure 1, the green label "Faol" means that a database record is active. It must not be interpreted as a positive seismic assessment. Administrative status and engineering status should be stored and displayed separately.

Illustrative results and discussion

A five-check example

Consider a hypothetical two-storey reinforced-concrete building. To demonstrate the method, five checks are selected from a larger assessment checklist. All numerical values in Table 2 are invented, and the drift limit of 0.004 is an assumption for this example, not a quoted Uzbek code limit. No result in the table describes a building shown in Figure 1.

Table 2

Synthetic inputs and results for the selected checks

Check	Input values	Calculation	Outcome
Column shear	Demand: 180 kN Resistance: 200 kN	ρ = 0.90	Pass
Beam shear	Demand: 90 kN Resistance: 80 kN	ρ = 1.125	Fail
First-storey drift	Movement: 9 mm Height: 3,000 mm Assumed limit: 0.004	θ = 0.003	Pass
Beam-column joint	Detailing not verified	Not calculated	Not checked
Foundation	Soil report unavailable	Not calculated	Not checked

Source: illustrative values selected for this paper; not field measurements or a complete building assessment.

The column check passes because 180/200 = 0.90. The beam check fails because 90/80 = 1.125: its assumed demand is 12.5% greater than its assumed resistance. The drift check passes against the example's assumed limit because 9/3,000 = 0.003 < 0.004. The other two checks cannot be completed. Missing joint or soil information does not itself prove a physical defect.

For this five-check subset, $N_a = 5$, $N_e = 3$ and $N_p = 2$. Equation (3) gives C = 3/5 × 100% = 60%. Equation (4) gives P = 2/3 × 100% ≈ 66.7%. In plain terms, three checks were completed and two of those passed. The building cannot be described as "66.7% earthquake-resistant."

The report should state: one strength check failed, and two checks require additional evidence. The next steps are engineering review of the beam result, verification of joint detailing and investigation of foundation conditions. The confirmed failure and the missing evidence are reported separately because they call for different actions.

Interpretation and validation needs

A simple sensitivity check illustrates why both percentages are needed. If the assumed beam resistance is changed to 100 kN, its ratio becomes 0.90 and all three completed checks pass. P rises to 100%, but C stays at 60%. The unresolved joint and foundation checks still prevent a

complete conclusion. This is a second synthetic scenario, not evidence of a real repair.

Before practical deployment, the rules should be tested against independent engineer calculations, including values at the acceptance boundary, missing inputs and conflicting document editions. Any accuracy or time-saving claim requires a documented validation dataset. The present example demonstrates arithmetic and reporting logic only.

3. Conclusion

A useful automated seismic-assessment system must do more than retrieve regulatory text. It must identify the applicable requirement, use verified building evidence, perform an approved comparison and explain the result. The proposed method gives each check a clear outcome and preserves the distinction between a detected deficiency and insufficient information.

The four equations have separate purposes: demand-to-capacity and drift ratios support engineering checks, while coverage and pass rate describe the progress and results of the selected checklist. Neither percentage is a seismic safety certificate. The synthetic example shows how a failed check and missing evidence remain visible. Further work should validate the rules on real buildings using approved regulatory texts and independent expert review. Final decisions about seismic resistance remain the responsibility of qualified structural engineers.

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Information about the author

Diyorbek Bekmirzaev	Institute of Mechanics and Seismic Stability of Structures named after M.T. Urazbaev E-mail: diyorbek_84@mail.ru
Ibrakhim Mirzaev	National Research Institute for Seismic Safety and Resilient Construction under Tashkent Institute of Architecture and Civil Engineering, Tashkent State Transport University E-mail: ibrakhim.mir@mail.ru
R. Yuldoshev	National Research Institute for Seismic Safety and Resilient Construction under Tashkent Institute of Architecture and Civil Engineering E-mail: aloqa@suvoriy.com

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